PREDICTING LARGE-SCALE FIRE TEST RESULTS OF COMPOSITES

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INTRODUCTION

The U.S. Coast Guard has responsibility for ensuring adequate safety for passengers and crew onboard commercial vessels. They accomplish this by establishing and enforcing construction and operating regulations both domestically and internationally. The International Code of Safety for High-Speed Craft (HSC Code) is a regulation that addresses safety concerns onboard high-speed craft and was prepared to allow new types of ship construction for fast sea transportation, while maintaining a high degree of safety for passengers and crew.

In accordance with the HSC Code, only materials that pass the International Standard Organization (ISO) 9705 Room/Corner Test may be used as compartment linings. This test generally consists of lining the ceiling and walls of a standard size room, exposing the corner of the room to a fire and evaluating how much heat and smoke are produced over a defined time period. Large quantities of the test material are required, so manufacturers of these materials are reluctant to pursue development of new and improved products. If a test method that did not require such large quantities of material could be used for regulation, manufacturers would potentially be more inclined to develop improved products. Additionally, a simpler (i.e., small-scale) test method would make regulation by the U.S. Coast Guard easier to accomplish.

Reliable and accurate prediction of full-scale performance from small-scale testing is a concern in the area of fire safety. The work documented in "Prediction of ISO 9705 Room/Corner Test Results" (CG-D-22-99), was conducted to see just how well the ISO 9705 Test results could be predicted from results obtained from small-scale test methods. This was a first step toward the goal of using a small-scale test method as a regulatory tool. Three separate fire research organizations used the Cone Calorimeter and LIFT Apparatus as two small-scale tests to evaluate the degree of predictability of large-scale test results for several materials.

The room/corner fire scenario has been recognized to be a challenging configuration and tests like ISO 9705 are recognized as real scale fire tests, which reasonably represent the hazards of interior, finish materials. While the room/corner fire test is recognized to be realistic, it is not useful for material development due to its high cost and large material requirements. The most highly developed bench scale fire tests, which have potential to relate to actual fire performance, are the Cone Calorimeter and the LIFT tests. Two means of relating Cone Calorimeter data to full-scale performance will be evaluated which include; correlations and mathematical models.

CORRELATION OF ROOM/CORNER FIRE BEHAVIOR

The correlating parameter developed here is the parameter in the linearized upward flame spread model, which determines if the flame spread accelerates or decays. The parameter, which has been called the Flammability Parameter, FP, is given by

$$FP = k_f \dot{E}'' - t_f / t_b$$

If FP is greater than one, the linearized model results in acceleratory spread. This parameter was used to correlate corner fire tests involving textile interior finish materials where the time to ignition in the Cone Calorimeter is t_f, the time to the peak heat release in the Cone Calorimeter is t_b, the peak heat release rate is E", and k_f represents a flame height parameter. The correlation was most satisfactory if cone data at 50 kW/m^2 was used. Attempts were made to use this method to correlate additional data from U.S. Navy room/corner tests and it was found that the two data sets did not follow the same correlation. On examination, it became clear that by redefining the means of deducing t_b and E", a single correlation for the two data sets could be accomplished. Beyler *et al*., defined t_b to be the duration of burning of the sample and E" to be the average heat release rate over this period. Using these definitions the peak heat release rate in the room/corner tests could be correlated for the two data sets together. The results presented here are for this modified correlational method as applied to a wide range of available data for materials which have been tested in the cone calorimeter and in room/corner tests.

The HSC Code defines performance requirements for use with ISO 9705. The peak heat release rate must be less than 500 kW and the test average heat release rate must be less than 100 kW. Based on all the testing, all materials with FP<0 passed the IMO heat release rate criteria and none of the materials caused flashover. The results are mixed in the range 0 > FP> 0.5 transition range, with some materials in this range passing while others fail. Materials with FP > 0.5 overwhelmingly fail the HSC criteria, though there are several materials (Swedish and LSF) with FP> 0.5 which pass one or both of the heat release rate criteria. Based on the available information, the reasons for the failure of the correlation for these materials is unclear. Nonetheless, the value of the flammability parameter as a screening tool is well established by this work, and the potential for the use of the cone calorimeter and the Flammability Parameter as a regulatory tool at some time in the future is promising.

ROOM/CORNER FIRE GROWTH MODELING

The model results when used to predict the USCG ISO 9705 full-scale room fire tests are presented and compared with the test data. The ISO 9705 room fire tests were performed on a variety of composite materials for the U. S. Coast Guard. A complete description of the model is included in the full report.

The model correctly predicts which materials will cause flashover and predicts the time of flashover to within 2 minutes in all tests. For those materials that do not cause flashover, the tendency is to underpredict the average and peak heat release rates. The comparisons of peak heat release rate for materials that flashover the compartment are not meaningful, since these tests were terminated artificially. The average heat release rates in these tests is the average up to the time of flashover, so this comparison is meaningful. Overall the performance of the model in predicting flashover and heat release is quite good.

Predictions of smoke generation make use of the heat release rate predictions and the specific extinction area measured in the cone calorimeter. The predictions are generally very low, especially among the materials where flashover did not occur. It is hypothesized that this is the result of smoke production from material, which did not burn during the test. The model includes smoke generated during burning and does not include smoke generated by simple pyrolysis of material beyond the flame front. Since the standard cone calorimeter testing does not evaluate smoke generation from material, which is not burning, there is no means to include this contribution. Additional work is needed in this important area. At this time, the model does not adequately predict smoke generation in the ISO 9705 test.

CONCLUSION

The opportunity exists to obtain significant information concerning expected ISO 9705 performance from a few tests of small samples. The Flammability Parameter is a powerful material development tool and its value as a screening tool is well established by this work. Additionally, the potential for the use of the cone calorimeter and the Flammability Parameter as regulatory tools at some time in the future is promising. Obviously, additional research is required to reach the goal of relying on small-scale test results for regulatory purposes. However, the research completed in this study clearly indicate that manufacturers can benefit from evaluating new materials in small-scale tests prior to investing in larger quantities of materials for the large-scale ISO 9705 Tests.

A full copy of the "Prediction of ISO 9705 Room/Corner Test Results" (CG-D-22-99) report is available through the USCG R&D Center's Internet site at the following location: www.rdc.uscg.mil/Reports/CGD2299Rpt.pdf or contact Mr. Dolph at 860-441-2817.